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(54) **LATENCY COMPENSATION FOR IMAGE PROCESSING DEVICES**

(57) The present invention relates to latency compensation for image processing devices. In order to assign overlay data to frames of a raw image stream (210), past frames within a selection of frames of the raw image stream are considered, which past frames already underwent image processing. A current frame of the raw image stream (210) is compared to the past frames contained in the selection of frames, and that one of the past

frames is identified that is most similar to the current frame. Overlay data from the identified past frame are chosen and assigned to the current frame. Thus, the current frame can be presented together with the assigned overlay data chosen from the most similar past frame and without the need to wait for the result of a computationally expensive and time-consuming image processing of the current frame.

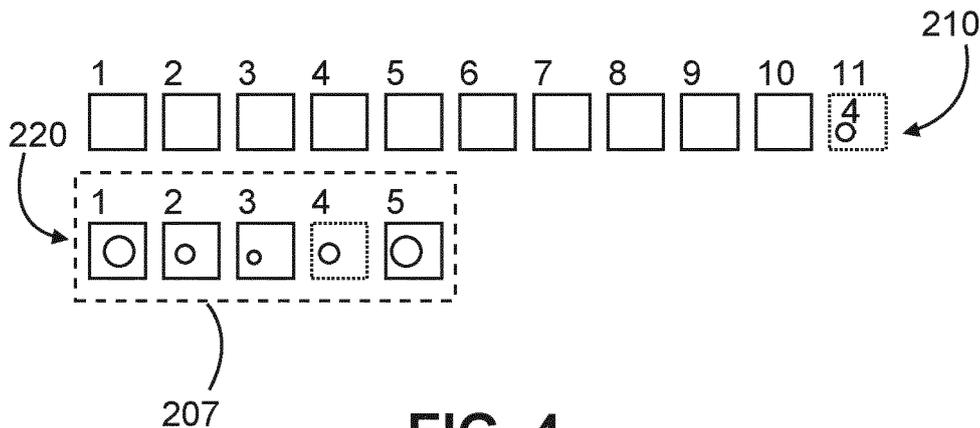


FIG. 4

Description

FIELD OF THE INVENTION

[0001] The present invention relates to image processing, in particular to an image processing device, to a medical imaging arrangement for processing images, and to a method for processing images. More particularly, the present invention relates to image processing of images that are presented to a user together with overlay data that are determined by an image processing algorithm.

BACKGROUND OF THE INVENTION

[0002] For several uses and applications, image frames of a raw image stream are processed to obtain overlay data that are assigned to the frames of the raw image stream, while the overlay data are presented to an operator or a user together with the frames of the raw image stream. Such an approach may generally be referred to as augmented imaging.

[0003] For example, in the field of medical imaging devices, interventional guidance applications may be used to show the position of a device like a catheter tip or stent with respect to the body of a person. In such applications, information about the device may be generated by an image processing algorithm and presented to an operator/user together with the raw image stream obtained from an image source like an X-ray or the like. The added information may be referred to as overlay data. The overlay data may highlight or emphasize the contours of the device or may be any other information obtained from the frames of the raw image stream. For example, in cardiac applications, a stent position may be visually enhanced in relation to a vessel wall.

[0004] The overlay data are typically generated by an image processing algorithm. However, it takes a certain time to determine or generate the overlay data so that there may be a time lag between capturing the frames of the raw image stream and presenting the frames together with the assigned overlay data to a user.

SUMMARY OF THE INVENTION

[0005] There may thus be a need for reducing the time lag between capturing the raw image stream and presenting the frames of the raw image stream together with overlay data to an operator/user.

[0006] The object of the present invention is solved by the subject-matter of the independent claims; further embodiments are incorporated in the dependent claims. It should be noted that the following described aspects of the invention apply also for the image processing device, for the medical imaging arrangement for processing images, and for the method for processing images.

[0007] According to the present invention, an image processing device is provided. The image processing device comprises a processor, a data memory, an input

interface, and an output interface. The input interface provides a raw image stream with a plurality of frames to the processor. The output interface provides an output image stream to a display. The processor is configured to: receive the raw image stream; process the frames of the raw image stream to thereby obtain a processed image stream, wherein the processed image stream is composed of the raw image stream and overlay data containing additional information compared to the raw image stream; provide the raw image stream and the overlay data to the data memory; generate a selection of frames of past frames of the raw image stream, wherein the selection of frames has a predetermined size and contains a number of past frames corresponding to the predetermined size; compare a current frame of the raw image stream with at least some frames of the selection of frames; determine a similarity value for the current frame and at least some frames of the selection of frames; identify that frame of the selection of frames with the highest similarity value to the current frame; assign the overlay data from the identified frame of the selection of frames to the current frame; and generate the output image stream based on the current frame and the assigned overlay data from the identified frame of the selection of frames.

[0008] This provides an output image stream that contains overlay data assigned to the data of the captured raw image stream. At least in a first stage, the overlay data of a current frame are the result of a similarity comparison between the current frame of the raw image stream and past frames of the raw image stream that already underwent image processing. From those past frames of the raw image stream, that one of the frames is selected that is most similar to the current frame. Then, the overlay data of that most similar frame is selected and the selected overlay data is assigned to the current frame. The most similar frame of the past frames is considered the closest visual substitute for the current frame. Therefore, it can be assumed that the overlay data of the closest visual substitute also match to the current frame. Instead of waiting for the processing results of a computationally expensive and time-consuming image processing algorithm that generates the overlay data for the current frame, the overlay data of the most similar past frame is selected to be presented together with the current frame. The operation of comparing the current frame of the raw image stream to past frames of the raw image stream may require far less computing power than the image processing algorithm. Therefore, the overlay data selected from the most similar past frame is available for presentation to an operator/user sooner than the results of the image processing algorithm. Thereby, a time lag of presenting the frames of the raw image stream together with overlay data is reduced.

[0009] According to an embodiment, the processor is configured to determine the selection of frames of the raw image stream by applying a sliding window algorithm to past frames of the raw image stream that passed an

image processing algorithm.

[0010] In this embodiment, the selection of frames is composed of frames of the raw image stream that already underwent processing by an image processing algorithm to generate the relating overlay data. Based on these frames, a selection of frames is generated as a basis for the comparison with the current frame. The sliding window algorithm may select the most recent ones of the frames that were processed by the image processing algorithm. This approach may result in high similarity between the frames of the selection of frames and the current frame.

[0011] According to an embodiment, the processor is configured to generate the overlay data based on the frames of the raw image stream and/or quantity values derived from the frames of the raw image stream.

[0012] According to an embodiment, the processor is configured to add the determined similarity value of the identified frame of the selection of frames with the highest similarity value to the output image stream.

[0013] In this embodiment, an operator is provided with information about the degree of similarity between the current frame and the most similar past frame. This degree of similarity may indicate the degree of accuracy of the overlay data of the past frame presented together with the current frame.

[0014] According to an embodiment, the processor is configured to compare the similarity value of the identified frame with the highest similarity value to a similarity threshold value and generate the output image stream to indicate if the similarity value is smaller than the similarity threshold value or equal to or larger than the similarity threshold value.

[0015] In this embodiment, the operator/user is provided with information about the degree of similarity between the current frame and the most similar past frame. This information may be an indicator for the level of accuracy of the overlay data.

[0016] According to an embodiment, no overlay data are selected from the past frames to be presented to an operator/user together with the current frame if the similarity value is smaller than a predetermined similarity threshold value. The rationale behind this is to avoid presenting overlay data from past frames that are, to a certain extent, different from the current frame.

[0017] According to an embodiment, the processor is configured to compare the overlay data that were assigned to a first frame of the raw image stream based on the selection of frames with overlay data resulting from an image processing algorithm applied to the first frame.

[0018] In this embodiment, the overlay data that were assigned to a first frame based on the similarity comparison with the past frames is compared to the overlay data that are generated by an image processing algorithm based on that first frame. This approach enables comparing the level of correspondence between the initially assigned overlay data and the finally determined overlay data. The operator/user of the image processing device

or of a medical imaging arrangement comprising such an image processing device may decide based on this information whether or not to use the overlay data estimation process (i.e., identifying overlay data based on the similarity between the current frame and a past frame) with reduced time lag or if the operator/user prefers to wait for the overlay data actually resulting from a time-consuming image processing algorithm.

[0019] According to the present invention, also a medical imaging arrangement for processing images is provided. The medical imaging arrangement comprises an image sensor, a display, and an image processing device as described in one or more embodiments above and hereinafter. The image sensor is communicatively coupled to the image processing device to provide a raw image stream to the image processing device and the display is communicatively coupled to the image processing device to receive an output image stream from the image processing device.

[0020] According to an embodiment, the imaging system is an X-ray system, a magnetic resonance imaging, MRI, device, a tomography device, an echocardiography device, an ultrasound device, a photoacoustic imaging device, or the like.

[0021] The image sensor may be any device suitable for capturing images in accordance to the technology of a particular imaging system. The image sensor may be a device that is specifically designed for a certain imaging system technology. However, the image sensor may provide the raw image stream in accordance with known standards so that an interface between the image sensor and the image processing device is standardized and does not need to be adapted to different imaging technologies. Nonetheless, the image processing device may contain proprietary interfaces to be communicatively coupled to different image sensors.

[0022] The display may be any type of device suitable for visually displaying information to a human operator/user. For example, the display may be a monitor or a plurality of monitors.

[0023] Of course, the principles as presented with respect to the image processing device apply to the medical imaging arrangement.

[0024] According to the present invention, also a method for processing images is provided. The method comprises the following steps: receiving a raw image stream with multiple frames; processing the frames of the raw image stream to thereby obtain a processed image stream, wherein the processed image stream is composed of the raw image stream and overlay data containing additional information compared to the raw image stream; providing the raw image stream and the overlay data to a data memory; generating a selection of frames of past frames of the raw image stream, wherein the selection of frames has a predetermined size and contains a number of past frames corresponding to the predetermined size; comparing a current frame of the raw image stream with at least some frames of the selection of

frames; determining a similarity value for the current frame and at least some frames of the selection of frames; identifying that frame of the selection of frames with the highest similarity value to the current frame; assigning the overlay data from the identified frame of the selection of frames to the current frame; generating an output image stream based on the current frame and the assigned overlay data from the identified frame of the selection of frames.

[0025] Functional features described above with reference to embodiments of the image processing device may be implemented as method steps of the method for processing images.

[0026] Furthermore, a computer program element is provided. The computer program element is configured for controlling an image processing device as described herein, which, when being executed by a processing unit, is adapted to perform the method steps of a method for processing images described herein.

[0027] Last, a computer readable medium is provided having stored the computer program element thereon.

[0028] According to an aspect, the devices and methods described herein relate to latency compensation for image processing devices. In order to assign overlay data to frames of a raw image stream, past frames within a selection of frames of the raw image stream are considered, which past frames already underwent image processing by an image processing algorithm. A current frame of the raw image stream is compared to the past frames contained in the sliding window, and that one of the past frames is identified that is most similar to the current frame. Overlay data from the identified past frame are chosen and assigned to the current frame. Thus, the current frame can be presented together with the assigned overlay data chosen from the most similar past frame and without the need to wait for the result of a computationally expensive and time-consuming image processing of the current frame.

[0029] These and other aspects of the present invention will become apparent from and be elucidated with reference to the embodiments described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] Exemplary embodiments of the invention will be described in the following with reference to the following drawings:

Fig. 1 schematically shows an image processing device according to an embodiment.

Fig. 2 schematically shows an imaging arrangement according to an embodiment.

Fig. 3 schematically shows a raw image stream and a time lag resulting from an image processing algorithm applied to the frames of the raw image stream.

Fig. 4 schematically shows assigning overlay data of past frames to a current frame of a raw image stream.

Fig. 5 schematically shows assigning overlay data of past frames to a current frame of a raw image stream.

Fig. 6 schematically shows comparing the assigned overlay data of a frame to generated overlay data of that frame.

Fig. 7 schematically shows the steps of a method for processing images according to an embodiment.

10 DETAILED DESCRIPTION OF EMBODIMENTS

[0031] Certain embodiments will now be described in greater details with reference to the accompanying drawings. In the following description, like drawing reference numerals are used for like elements, even in different drawings. The matters defined in the description, such as detailed construction and elements, are provided to assist in a comprehensive understanding of the exemplary embodiments. Also, well-known functions or constructions are not described in detail since they would obscure the embodiments with unnecessary detail. Moreover, expressions such as "at least one of", when preceding a list of elements, modify the entire list of elements and do not modify the individual elements of the list.

[0032] Fig. 1 schematically shows an embodiment of an image processing device 10.

[0033] The device 10 comprises a processor 20, a data memory 30, an input interface 40, and an output interface 50. The input interface 40 is configured to provide a raw image stream with a plurality of frames to the processor 20. The output interface 50 is configured to provide an output image stream to a display. The processor 20 is configured to receive the raw image stream, process the frames of the raw image stream to thereby obtain a processed image stream, wherein the processed image stream is composed of the raw image stream and overlay data containing additional information compared to the raw image stream, provide the raw image stream and the overlay data to the data memory 30, generate a selection of frames of past frames of the raw image stream, wherein the selection of frames has a predetermined size and contains a number of past frames corresponding to the predetermined size, compare a current frame of the raw image stream with at least some frames of the selection of frames, determine a similarity value for the current frame and at least some frames of the selection of frames, identify that frame of the selection of frames with the highest similarity value to the current frame, assign the overlay data from the identified frame of the selection of frames to the current frame, and generate the output image stream based on the current frame and the assigned overlay data from the identified frame of the selection of frames.

[0034] A basic aspect of this approach is to compensate for latency that is introduced by computational demanding and/or time-consuming image processing algorithms applied to frames of an image stream. For exam-

ple, if additional information, i.e., the overlay data, are to be rendered into an image stream, this process requires a certain amount of time. Depending on the image processing algorithms, the time lag introduced by the image processing stream may be significant. For some applications, a time lag of several seconds may be undesirable or unacceptable, e.g. medical imaging devices.

[0035] The compensation of the latency is done by comparing current image frames of a real-time image stream, i.e., the raw image stream, with past frames of the same real-time image stream that already underwent the image processing algorithm to determine the overlay data. The overlay data may be results of the image processing algorithm, wherein the results are rendered into the individual frames of the real-time image stream. For diagnostic imaging processes, additional information is rendered into the raw image stream, for example a catheter tip or stent, to make visual inspection of the displayed image frames easier and more comfortable. When the catheter tip is moved, latency between the tip movement and the processed image stream is introduced because rendering the information relating to the catheter tip into the raw image stream is a process that is computationally costly.

[0036] The raw image stream comprises multiple frames. The most recent frame is referred to as current frame. However, in order to render the additional information into the current frame, a certain amount of processing time is required which introduces time lag.

[0037] The raw image stream originates from an image source, e.g., a fluoroscopy imaging device like an X-ray, magnetic resonance imaging device, ultrasonic device and the like. The raw image stream may also be a recorded image stream originating from a data storage.

[0038] At least some or all past frames of the raw image stream and the assigned overlay data are at least temporarily stored in the data memory 30. A selection of frames of the raw image stream are considered for being compared with the current frame of the raw image stream. Comparing two images, i.e., comparing the current frame of the raw image stream with at least one, more, or each of the selection of past frames of the raw image stream, requires far less computation time than image processing operations. The current frame of the raw image stream is compared to at least one, some, or each of the frames of the selection of past frames of the raw image stream. Thus, multiple image comparison operations are carried out, wherein a respective image comparison operation is applied to two images, i.e., the current frame and one past frame. For at least some of these image comparison operations, a similarity value is calculated for the pair of compared frames. Then, the pair of frames with the highest similarity is selected to identify a past frame that is most similar to the current frame. Based on the identified most similar past frame, the overlay data rendered into that (past) frame is selected from the data memory and also rendered into the current frame of the raw image stream. The additional information that is rendered into

the frames of the raw image stream is referred to as overlay data. The frames of the raw image stream and the overlay data are presented to an operator of an imaging device.

5 **[0039]** For example, in cardiac applications, this approach helps to visually enhance the catheter tip in relation to a vessel wall with a small time lag. The visually enhanced optical characteristics are overlaid to the frames of the raw image stream to highlight or emphasize features of the frames of the raw image stream. This composition of optical features, i.e., frames of the raw image stream and the additional optical characteristics, are referred to as processed image stream.

10 **[0040]** Comparing the current frame of the raw image stream with the past frames of the raw image stream can be done by any applicable image comparing algorithm. For example, at least some of structures, lines, shapes, brightness appearing in those frames can be taken into consideration in order to calculate a similarity value. For example, the similarity value can be calculated by sum of squared differences between intensity values of the frames. It is assumed that the image processing results of similar frames are similar. This is why the additional information rendered into a past frame can be rendered into the current frame if the current frame is identical or similar (to a certain degree) to said past frame.

15 **[0041]** In one embodiment, the comparison may be done by using only a selected part or selected region of the past frames. For example, the selected region around the overlay data is considered for comparison with the current frame. The selected region around the overlay data may be defined as that region of a past frame where the overlay data is located. The selected region is larger than the overlay data. Furthermore, in the comparison process, an image transformation like a shift between a region of interest of the past images with respect to the current frame may be determined. When assigning the overlay data of a past frame to the current frame, the transformation may also be applied to the overlay data.

20 **[0042]** In other words, the invention proposes to compare a current frame to a selection of past frames that already underwent image processing and is assigned to overlay data, identify that one of the past frames that is most similar to the current frame, and compose an output image stream based on the current frame and the overlay data of the most similar past frame.

25 **[0043]** Fig. 2 exemplarily shows a medical imaging arrangement 100. The imaging arrangement 100 comprises an image sensor 60, an image processing device 10, for example the device described with reference to Fig. 1, and a display 70. The image sensor 60 is communicatively coupled to the image processing device to provide a raw image stream to the image processing device. Particularly, the image sensor 60 provides the raw image stream to an input interface 40 of the image processing device 10 and the input interface provides the raw image stream to the processor 20. For example, the image sensor 60 may be coupled to the image processing device

10 by a wired or wireless connection. In one embodiment, the image sensor 60 and the image processing device 10 may be connected by a data transmission network that is comprises of multiple segments of which some may be wired segments and others may be wireless segments. The display 70 is communicatively coupled to the image processing device 10 to receive an output image stream from the image processing device. For the communicative coupling of the display 70 and the device 10, the same principles apply as described with reference to the coupling of the image sensor 60 and the image processing device 10.

[0044] It is noted that the imaging system 100 of Fig. 2 may comprise the image processing device 10 described with reference to any embodiment or example contained herein.

[0045] According to an embodiment, the imaging system 100 is an X-ray system, a magnetic resonance imaging, MRI, device, a tomography device, an echocardiography device, an ultrasound device, a photoacoustic imaging device, or the like.

[0046] The image sensor 60 may be any device suitable for capturing images in accordance to the technology of a particular imaging system. The image sensor 60 may be a device that is specifically designed for a certain imaging system technology. However, the image sensor 60 may provide the raw image stream in accordance with known standards so that an interface between the image sensor 60 and the image processing device 10 is standardized and does not need to be adapted to different imaging technologies. Nonetheless, the image processing device may contain proprietary interfaces to be communicatively coupled to different image sensors.

[0047] The principles of image processing as implemented by the image processing device 10 and the method for image processing disclosed herein are further described with reference to Fig. 3 to Fig. 6.

[0048] Fig. 3 shows a raw image stream 210 with multiple frames numbered from 1 to 17 in accordance with the time these frames are captured and/or provided to the image processing device. In other words, frame 1 is provided first, then, after a certain amount of time, frame 2 is provided, etc. When applying an image processing algorithm to the individual frames in order to generate overlay data for the frames, this operation requires a certain amount of time depending on the complexity of the image processing algorithm. The time required for finishing image processing for a frame is indicated by the time lag 205. The processed images are the output of an image processing algorithm and overlay data are assigned to at least some or all frames of the raw image stream. The overlay data are shown by circles within the individual frames. However, it is noted that the overlay data may be any data generated based on the frames of the raw image stream. Examples of overlay data are provided above and hereinafter with reference to other examples and embodiments.

[0049] Fig. 4 shows a raw image stream with eleven

frames and frame 11 being the most recent frame, i.e., the current frame. In this embodiment, it is assumed that frames 1 to 5 of the raw image stream 210 underwent image processing by the image processing algorithm and the overlay data for frames 1 to 5 are available, such that the frames 1 to 5 with the assigned overlay data correspond to the processed images 220.

[0050] In one embodiment and with reference to the image processing device 10 of Fig. 1, the processor 20 is configured to determine the selection of frames of the raw image stream by applying a sliding window algorithm to past frames of the raw image stream that passed an image processing algorithm.

[0051] The selection of frames corresponds to the sliding window 207 containing five frames (frame 1 to frame 5) of the processed images 220. The current frame, i.e., frame 11, of the raw image stream 210 is compared to at least one, some or all frames that are contained in the sliding window 207 to determine the most similar frame within the sliding window. For example, if it is determined that frame 4 of the sliding window 7 is most similar to the current frame 11, the overlay data of frame 4 are selected and assigned to and rendered into the current frame. In Fig. 4, frame 11 (current frame) and frame 4 (the past frame that is most similar to the current frame) are shown with dotted lines for purposes of illustration only and in order to point out that these two frames are most similar to each other.

[0052] At least some or each of the frames of the selection of frames of the raw image stream is compared to the current frame of the raw image stream. The likelihood for finding a similar frame may increase when comparing frames that are captured about the same time or in temporal proximity. Therefore, once a frame is processed, it is entered into the selection of frames as the most recent frame that passed image processing. The entirety of frames of the current image stream that have passed image processing may be referred to as processed image stream. Thus, the frames of the processed image stream are a subset of the raw image stream and refers to those frames for which the image processing algorithm has identified the overlay data. The most recent frame of the processed image stream steps into the selection and the most past frame of the processed image stream drops out of the selection. In other words, the sliding window works like a buffer that implements the first-in-first-out principle.

[0053] In one embodiment, other parameters that are known to affect the image similarity may be used to select the past frames contained within the sliding window. For example, in a periodical process, frames taken during the same or close to the same point of time with reference to the periodic process. Specifically, if the current frame is taken from the human heart and during an end-diastolic heart phase, the sliding window may contain past frames that were taken close to or during end-diastolic heart phase from previous heartbeat cycles.

[0054] Fig. 5 exemplarily shows the scenario that fol-

lows the scenario shown in Fig. 4. In Fig. 5, the raw image stream 210 contains twelve frames with frame 12 being the current frame. At this point in time, one more frame might have undergone image processing by the image processing algorithm so that the processed images 220 contain six frames, i.e., frame 1 to frame 6. The sliding window 207 shifts one position to the right to contain the most recent five frames, i.e., frame 2 to frame 6. The current frame 12 is compared to frames 2 to 6 within the sliding window to identify the most similar frame (in this embodiment: frame 6) and to then select the overlay data from that most similar past frame and render the selected overlay data into frame 12. As can be seen in Fig. 5, the sliding window contains the most recent frames of the processed images. In Fig. 5, frame 12 (current frame) and frame 6 (the past frame that is most similar to the current frame) are shown with dotted lines for purposes of illustration only and in order to point out that these two frames are most similar to each other.

[0055] In the embodiment described with reference to Fig. 4 and Fig. 5, the size of the sliding window 207 is five frames. However, it is noted that the size of the sliding window may be different from this size and may also vary during operation of the image processing device.

[0056] In one embodiment and with reference to the image processing device 10 of Fig. 1, the processor 20 is configured to adjust a number of frames within the selection of frames. Hence, the size of the sliding window is adjusted, i.e., increased or decreased.

[0057] In one embodiment and with reference to the image processing device 10 of Fig. 1, the processor 20 is configured to generate the overlay data based on the frames of the raw image stream and/or quantity values derived from the frames of the raw image stream.

[0058] The overlay data may either highlight elements contained in the frames of the raw image data or add a derived quantity to overlay the frames, e.g., cardiac volume or cardiac dimensions and to be displayed together with the frames. For example, the complete body of a structure may be labelled, or an algorithm may process a frame of the raw image stream and output a quantity value without labelling individual landmarks in the frame that lead to said quantity value. Furthermore, in one embodiment, the overlay data may be generated based on contours contained in the frames of the raw image stream.

[0059] In one embodiment and with reference to the image processing device 10 of Fig. 1, the processor 20 is configured to process multiple frames of the raw image stream 210 in parallel to thereby obtain a respective frame of the processed image stream 220 from each processing operation that is executed in parallel.

[0060] Assuming that the processing time per frame of the raw image stream takes about a constant time, the processor must be able to process multiple frames in parallel when the processing time is larger than the time between two subsequent frames of the raw image stream in order not to extend the processing time per individual

frame. For example, with a frame rate of 20 to 25 frames per second and a processing time of the algorithm that calculates the frames of the processed image stream of two seconds per frame, the processor must be able to process 50 frames in parallel in order not to extend the processing time per individual frame.

[0061] The processor may process at least some or each frame of the raw image stream in accordance with the principles set forth herein. However, in case of reduced computational power, the processor may process every second frame (or every third or higher number of frames) of the raw image stream.

[0062] In one embodiment and with reference to the image processing device 10 of Fig. 1, the processor 20 is configured to add the determined similarity value of the identified frame of the selection of frames with the highest similarity value to the output image stream.

[0063] The selection of past processed frames may not contain a frame that is absolutely identical to the current frame. For this reason, it might be helpful for an operator of an imaging device to know a grade of similarity between the current frame and the identified most similar frame of the selection of past frames. This grade of similarity may be an indication of how accurate the overlay data of the past frame fit to the current frame. The similarity value or a percentage value indicating the similarity between the current frame and the selected past frame may be displayed on the display 70 together with the frames of the output image stream.

[0064] In one embodiment and with reference to the image processing device 10 of Fig. 1, the processor 20 is configured to compare the similarity value of the identified frame with the highest similarity value to a similarity threshold value, and generate the output image stream to indicate if the similarity value is smaller than the similarity threshold value or equal to or larger than the similarity threshold value.

[0065] This allows for defining a similarity threshold value which indicates the minimum required similarity in order to generate minimum reliable output image streams based on the past frames. In this embodiment, the device indicates if the similarity between the current frame and the most similar past frame (of the selection of frames) is above or below the similarity threshold value. In case the similarity value is below the similarity threshold value, the output result may not be reliable to proceed with and the operator may choose to wait on the results of the image processing algorithm.

[0066] For example, either similarity value and/or a symbol may be displayed to indicate if the similarity values is smaller or greater than the similarity threshold.

[0067] In one embodiment and with reference to the image processing device 10 of Fig. 1, the processor 20 is configured to stop adding the overlay data to the current frame if the similarity value is smaller than the similarity threshold value.

[0068] In this embodiment, the overlay data is not added to the current frame when the similarity is too low so

that an operator of the image device is not misled by possible inaccurate overlay data.

[0069] In one embodiment and with reference to the image processing device 10 of Fig. 1, the processor 20 is configured to compare the overlay data that were assigned to a first frame of the raw image stream based on the selection of frames with overlay data resulting from an image processing algorithm applied to the first frame.

[0070] Fig. 6 is based on the embodiment shown in Fig. 4 and describes this embodiment in more details. As described with reference to Fig. 4, frame 11 of the raw image stream 210 is initially assigned the overlay data of frame 4 that was the most similar frame from the sliding window 207 at the time when frame 11 was captured or provided by the image sensor. However, Fig. 6 shows the scenario at a later time when frame 11 of the raw image stream 210 was processed by the (time-consuming) image processing algorithm. At the time shown in Fig. 6, the actual processing result of frame 11 is available and at this time, the overlay data initially assigned to frame 11 (see Fig. 4) can be compared to the overlay data resulting from the image processing algorithm (see Fig. 6). This comparison allows for determining the accuracy of the initially assigned overlay data. In Fig. 6, frame 17 is shown with dotted lines for purposes of illustration only and in order to point out that this frame is the current frame.

[0071] In other words, this embodiment allows for comparing the current image frame of the raw image stream together with the overlay data derived from the selection of past frames (may be referred to as estimated output) with the result of said current image frame being processed by an image processing algorithm (may be referred to as processed output). The accuracy of the estimated output depends on the grade of similarity between the current frame and the frames of the selection of past frames. If the past frames have a low level of similarity to the current frame, then the overlay data selected from the past frames and assigned to the current frame may also have a low accuracy. On the other hand, the processing results of the image processing algorithm are highly accurate. Therefore, this embodiment allows for determining the accuracy of the initially assigned overlay data in view of the overlay data resulting from the image processing algorithm.

[0072] In more details, a first frame of the raw image stream is assigned overlay data from a past frame that meets similarity criteria. This initially assigned overlay data may be referred to as estimated overlay data. However, this first frame undergoes image processing and at some time in the future, the processing results of the image processing are available. The processing results contain the computed overlay data based on the first frame. Then, the computed overlay data (result of the image processing algorithm) and the estimated overlay data (selected from the most similar past frame) are compared to each other to determine a similarity between these different overlay data.

[0073] With further reference to Fig. 3 to Fig. 6, an approach is described for compensating for visual latency introduced by image analysis algorithms when their results are rendered into real-time fluoroscopy. In this approach, a general method and device is described which allows to use computational costly image processing algorithms or algorithms hosted in a cloud computation center without introducing significant additional latency into the feedback loop. The display of frames and processing results remain synchronized and real-time although the transmission of images to the cloud may introduce significant latency.

[0074] Therefore, an additional, fast algorithm (the algorithm that compares the current frame to the already processed past frames) calculates for at least some or each frame in a sliding window 207 of frames (back in time) the image similarity to the current frame. The sliding window is positioned in such a way that for all frames in the sliding window 207 the processing result is available. The most similar frame within the sliding window can be seen as the closest visual substitute for the current frame, hence it can be assumed that the corresponding processing result is also close to the processing of the current frame (although the actual processing result of the current frame is not available yet). For the current frame the substitute processing result is overlaid to the original stream (raw image stream). When the current frame has been processed (a short time later) the processor compares the initially assigned overlay data (back in time) with current, true result. A large error may be indicated at the display to the operator and/or completely disable assigning overlay data from past frames to the respective current frame.

[0075] As an application example, during interventional X-ray, the operator may interactively change the position of a catheter tip/stent while visually inspecting the displayed image frames. In many interventional guidance applications not only the image frames are shown but also additional information (the overlay data), which is simultaneously extracted from the images. For example, in cardiac applications the stent position can be visually enhanced in relation to the vessel wall working against. A dedicated processing algorithm may fade out background noise and unwanted anatomical structures in the real-time image stream.

[0076] The additional processing by the image processing algorithm to calculate the overlay data usually introduces some latency between the tip movement and the output image stream. Only latency on the order of several hundreds of milliseconds may be accepted, otherwise catheter tip movements and image information may no longer be synchronized and make it difficult for the operator to relate the effect of the tip movement to the change of the visual image content.

[0077] The approach described herein allows to use computational costly image processing algorithms and/or transmission channels (for example connection between the image sensor 60 and the image processing

device 10 on the one hand and connection between the image processing device 10 and the display 70 on the other hand) without introducing significant latency into the feedback loop. The display of frames and processing results remain synchronized and real-time, although the overall data transmission and processing is on the order of several seconds per frame.

[0078] In Fig. 4, the segmentation result (result of the image processing algorithm) of frame 11 is unknown and the segmentation result of frame 4 is used and assigned to frame 11. However, after the acquisition of frame 17 (see Fig. 6) the true segmentation result of frame 11 is known. As depicted in Fig. 6 the substitute overlay data of frame 4 and the true segmentation result of frame 11 can now be compared to each other and quantitatively characterized to identify and indicate the accuracy of the initially assigned overlay data from frame 4 to frame 11. This indicates how close the overlay data of frame 4 were to the actually computed overlay data of frame 11. This step can be executed for the following frames as well and a sliding average may be presented to an operator/user as a retrospective quality measure or error measure in the display together with the current frames and overlay data. Based on the presented information, the operator may qualify how good the similarity algorithm has worked just a few frames before, and if the measure is below a certain quality threshold, the overlay data taken from the past frames will no longer be shown, as described with reference to certain embodiments. If the quality improves, the overlay data may be displayed again.

[0079] In one embodiment, a ventricle within the human body may be used for the segmentation of the ventricle as a guiding anatomical structure. However, a ventricle is used only for illustration. Any processing task which is based on individual frames (2D or 3D) can be used. With a frame rate of 20-25 frames per second and a processing time of 2 seconds per frame the algorithm may allow to process 50 frames in parallel without extending the processing time per individual frame.

[0080] The length of the sliding window can be larger as described above with reference to one embodiment, it can also vary over time, e.g., be increased or decreased over time. The calculation of the similarity measure may be on the order of several microseconds to meet the real-time constraints of ultrasound. Also, other similarity metrics can be used.

[0081] For cardiac applications, the similarity can be assessed not only frame by frame but also on the basis of complete heart cycles, hence the entire sequence of frames is compared (in one step) or the frame by frame comparison is guided position of the frames within the cycle to reduce the overall size of the sliding window.

[0082] The approach described herein may also be used in Ultrasound applications. In this case, the operator may not move a catheter tip or stent but a probe which steers the image formation process.

[0083] Fig. 7 shows an embodiment of a method 300 for processing images. In this embodiment, the method

300 comprises the following steps:

step 310: receiving a raw image stream with multiple frames

step 320: processing the frames of the raw image stream to thereby obtain a processed image stream, wherein the processed image stream is composed of the raw image stream and overlay data containing additional information compared to the raw image stream;

step 330: providing the raw image stream and the overlay data to a data memory;

step 340: generating a selection of frames of past frames of the raw image stream, wherein the selection of frames has a predetermined size and contains a number of past frames corresponding to the predetermined size;

step 350: comparing a current frame of the raw image stream with at least some frames of the selection of frames;

step 360: determining a similarity value for the current frame and at least some frames of the selection of frames;

step 370: identifying that frame of the selection of frames with the highest similarity value to the current frame;

step 380: assigning the overlay data from the identified frame of the selection of frames to the current frame;

step 390: generating an output image stream based on the current frame and the assigned overlay data from the identified frame of the selection of frames.

[0084] For the method 300 schematically shown in Fig. 7, the same principles apply as described with reference to the image processing device 10 and the medical imaging arrangement 100 described with reference to Fig. 1 to Fig. 6. Functional features described with reference to the image processing device 10 and the medical imaging arrangement 100 may be implemented as additional or optional steps of the method 300.

[0085] In one embodiment, the method comprises the steps of comparing the similarity value of the identified frame with the highest similarity value to a similarity threshold value, and generating the output image stream to indicate if the similarity value is smaller than the similarity threshold value or equal to or larger than the similarity threshold value.

[0086] In another embodiment, the method comprises the step of comparing the overlay data that were assigned to a first frame of the raw image stream based on the selection of frames with overlay data resulting from an image processing algorithm applied to the first frame.

[0087] In another exemplary embodiment of the present invention, a computer program or a computer program element is provided that is characterized by being adapted to execute the method steps of the method according to one of the preceding embodiments, on an

appropriate system, e.g., when being executed by a processing unit like the processor 20.

[0088] The computer program element might therefore be stored on a computer unit or be distributed over more than one computer units, which might also be part of an embodiment of the present invention. This computing unit may be adapted to perform or induce a performing of the steps of the method described above. Moreover, it may be adapted to operate the components of the above described apparatus. The computing unit can be adapted to operate automatically and/or to execute the orders of a user. A computer program may be loaded into a working memory of a data processor like the processor 20. The data processor may thus be equipped to carry out the method of the invention.

[0089] Aspects of the invention may be implemented in a computer program product, which may be a collection of computer program instructions stored on a computer readable storage device which may be executed by a computer. The instructions of the present invention may be in any interpretable or executable code mechanism, including but not limited to scripts, interpretable programs, dynamic link libraries (DLLs) or Java classes. The instructions can be provided as complete executable programs, partial executable programs, as modifications to existing programs (e.g. updates) or extensions for existing programs (e.g. plugins). Moreover, parts of the processing of the present invention may be distributed over multiple computers or processors.

[0090] As discussed above, the processing unit or processor 20, for instance a controller, implements the method as described with reference to some embodiments. The controller can be implemented in numerous ways, with software and/or hardware, to perform the various functions required. A processor is one example of a controller which employs one or more microprocessors that may be programmed using software (e.g., microcode) to perform the required functions. A controller may however be implemented with or without employing a processor, and also may be implemented as a combination of dedicated hardware to perform some functions and a processor (e.g., one or more programmed microprocessors and associated circuitry) to perform other functions.

[0091] Examples of controller components that may be employed in various embodiments of the present disclosure include, but are not limited to, conventional microprocessors, application specific integrated circuits (ASICs), and field-programmable gate arrays (FPGAs).

[0092] This exemplary embodiment of the invention covers both, a computer program that right from the beginning uses the invention and a computer program that by means of an up-date turns an existing program into a program that uses the invention.

[0093] Further on, the computer program element might be able to provide all necessary steps to fulfil the procedure of an exemplary embodiment of the method as described above.

[0094] According to a further exemplary embodiment of the present invention, a computer readable medium, such as a CD-ROM, is presented wherein the computer readable medium has a computer program element stored on it which computer program element is described by the preceding section. A computer program may be stored and/or distributed on a suitable medium, such as an optical storage medium or a solid-state medium supplied together with or as part of other hardware, but may also be distributed in other forms, such as via the internet or other wired or wireless telecommunication systems.

[0095] However, the computer program may also be presented over a network like the World Wide Web and can be downloaded into the working memory of a data processor from such a network. According to a further exemplary embodiment of the present invention, a medium for making a computer program element available for downloading is provided, which computer program element is arranged to perform a method according to one of the previously described embodiments of the invention.

[0096] It has to be noted that embodiments of the invention are described with reference to different subject matters. In particular, some embodiments are described with reference to method type claims whereas other embodiments are described with reference to the device type claims. However, a person skilled in the art will gather from the above and the following description that, unless otherwise notified, in addition to any combination of features belonging to one type of subject matter also any combination between features relating to different subject matters is considered to be disclosed with this application. However, all features can be combined providing synergetic effects that are more than the simple summation of the features.

[0097] While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive. The invention is not limited to the disclosed embodiments. Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing a claimed invention, from a study of the drawings, the disclosure, and the dependent claims.

[0098] In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. A single processor or other unit may fulfil the functions of several items recited in the claims. The mere fact that certain measures are re-cited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.

Claims**1.** A image processing device (10), comprising:

a processor (20);
 a data memory (30);
 an input interface (40), configured to provide a raw image stream (210) with a plurality of frames to the processor (20);
 an output interface (50), configured to provide an output image stream to a display;
 wherein the processor (20) is configured to receive the raw image stream (210); to process the frames of the raw image stream (210) to thereby obtain a processed image stream (220), wherein the processed image stream (220) is composed of the raw image stream and overlay data containing additional information compared to the raw image stream (210); to provide the raw image stream (210) and the overlay data to the data memory (30); to generate a selection of frames of past frames of the raw image stream, wherein the selection of frames has a predetermined size and contains a number of past frames corresponding to the predetermined size; to compare a current frame of the raw image stream (210) with at least some frames of the selection of frames; to determine a similarity value for the current frame and at least some frames of the selection of frames; to identify that frame of the selection of frames with the highest similarity value to the current frame; to assign the overlay data from the identified frame of the selection of frames to the current frame; and to generate the output image stream based on the current frame and the assigned overlay data from the identified frame of the selection of frames.

2. The image processing device (10) according to claim 1, wherein the processor (20) is configured to determine the selection of frames of the raw image stream (210) by applying a sliding window algorithm to past frames of the raw image stream (210) that passed an image processing algorithm.

3. The image processing device (10) according to claim 2, wherein the processor (20) is configured to adjust a number of frames within the selection of frames.

4. The image processing device (10) according to one of the preceding claims, wherein the processor (20) is configured to generate the overlay data based on the frames of the raw image stream and/or quantity values derived from the frames of the raw image stream.

5. The image processing device (10) according to one

of the preceding claims, wherein the processor (20) is configured to process multiple frames of the raw image stream (210) in parallel to thereby obtain a respective frame of the processed image stream (220) from each processing operation that is executed in parallel.

6. The image processing device (10) according to one of the preceding claims, wherein the processor (20) is configured to add the determined similarity value of the identified frame of the selection of frames with the highest similarity value to the output image stream.

7. The image processing device (10) according to one of the preceding claims, wherein the processor (20) is configured to:

compare the similarity value of the identified frame with the highest similarity value to a similarity threshold value;
 generate the output image stream to indicate if the similarity value is smaller than the similarity threshold value or equal to or larger than the similarity threshold value.

8. The image processing device (10) according to claim 7, wherein the processor (20) is configured to stop adding the overlay data to the current frame if the similarity value is smaller than the similarity threshold value.

9. The image processing device (10) according to one of the preceding claims, wherein the processor (20) is configured to compare the overlay data that were assigned to a first frame of the raw image stream based on the selection of frames with overlay data resulting from an image processing algorithm applied to the first frame.

10. A medical imaging arrangement (100) for processing images, the arrangement comprising:

an image sensor (60);
 a display (70); and
 an image processing device (10) according to one of the preceding claims;
 wherein the image sensor (60) is communicatively coupled to the image processing device (10) to provide a raw image stream (210) to the image processing device (10); and
 wherein the display (70) is communicatively coupled to the image processing device (10) to receive an output image stream from the image processing device (60).

11. A method (300) for processing images, comprising the following steps:

receiving (310) a raw image stream (210) with multiple frames;
 processing (320) the frames of the raw image stream (210) to thereby obtain a processed image stream (220), wherein the processed image stream (220) is composed of the raw image stream and overlay data containing additional information compared to the raw image stream (210);
 providing (330) the raw image stream (210) and the overlay data to a data memory (30);
 generating (340) a selection of frames of past frames of the raw image stream, wherein the selection of frames has a predetermined size and contains a number of past frames corresponding to the predetermined size;
 comparing (350) a current frame of the raw image stream (210) with at least some frames of the selection of frames;
 determining (360) a similarity value for the current frame and at least some frames of the selection of frames;
 identifying (370) that frame of the selection of frames with the highest similarity value to the current frame;
 assigning (380) the overlay data from the identified frame of the selection of frames to the current frame; and
 generating (390) an output image stream based on the current frame and the assigned overlay data from the identified frame of the selection of frames.

15. A computer readable medium having stored the computer program element of claim 14.

12. The method according to claim 11, further comprising:

comparing the similarity value of the identified frame with the highest similarity value to a similarity threshold value;
 generating the output image stream to indicate if the similarity value is smaller than the similarity threshold value or equal to or larger than the similarity threshold value.

13. The method according to claim 11 or 12, further comprising:

comparing the overlay data that were assigned to a first frame of the raw image stream based on the selection of frames with overlay data resulting from an image processing algorithm applied to the first frame.

14. A computer program element for controlling an image processing device (10) according to one of the claims 1 to 9, which, when being executed by a processing unit, is adapted to perform the method steps of one of the claims 11 to 13.

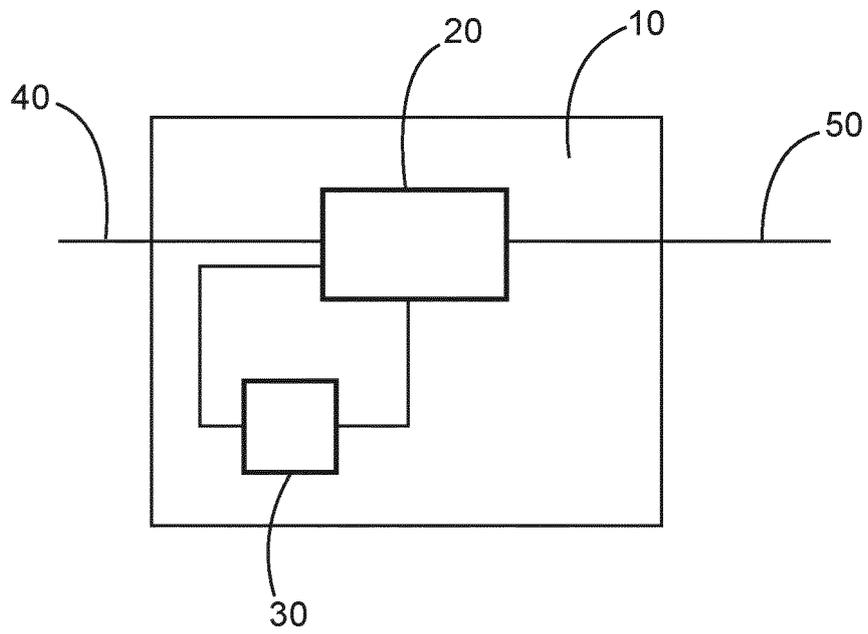


FIG. 1

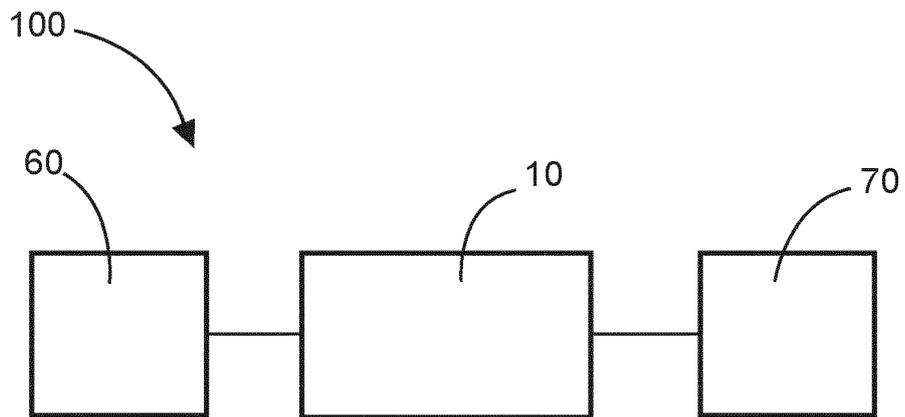


FIG. 2

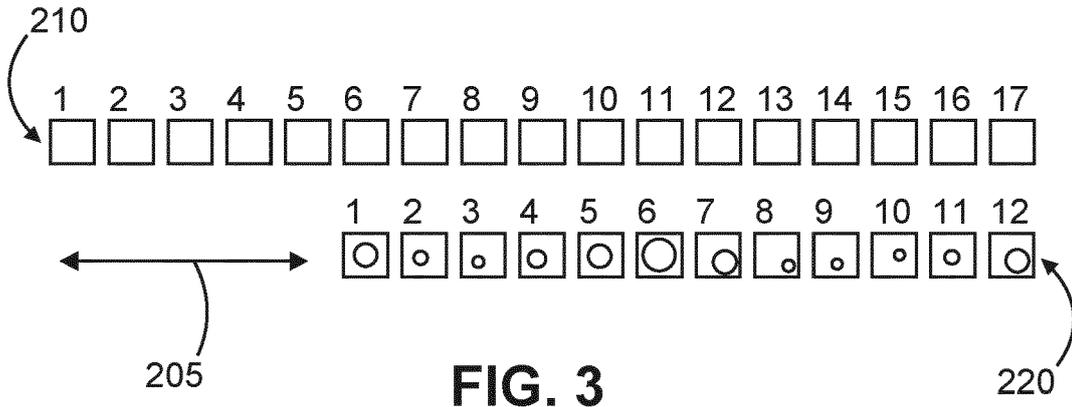


FIG. 3

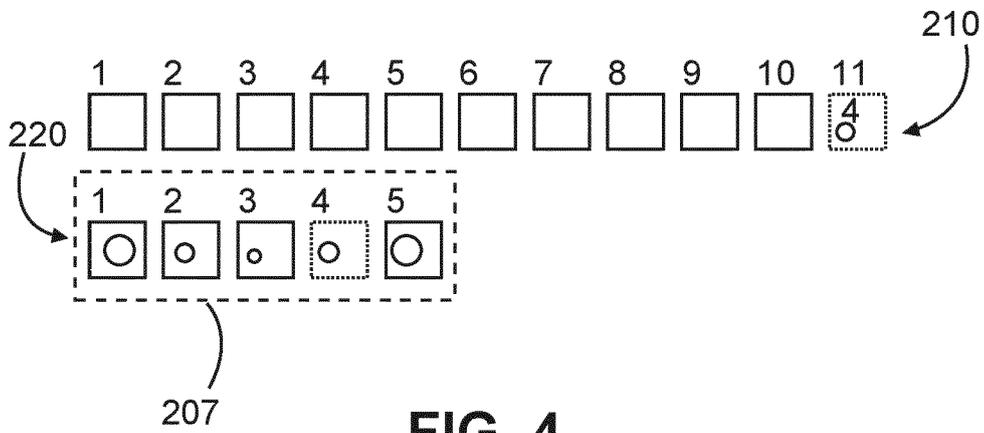


FIG. 4

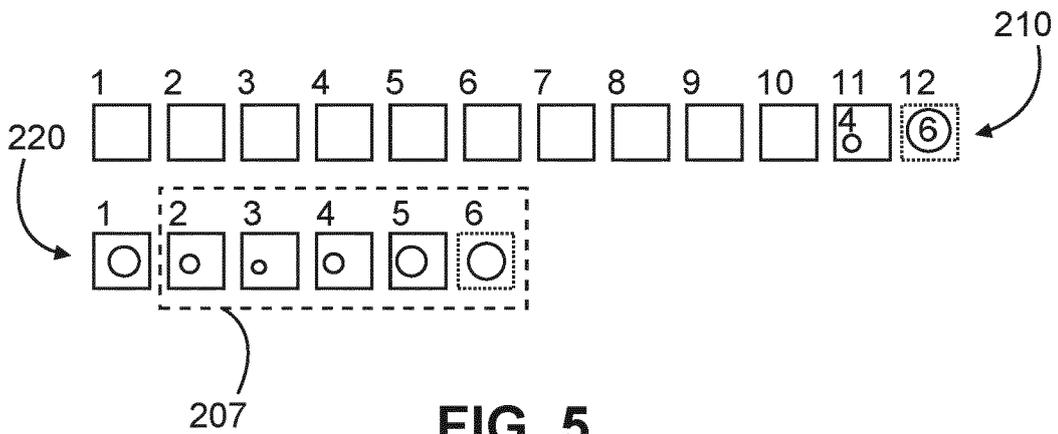


FIG. 5

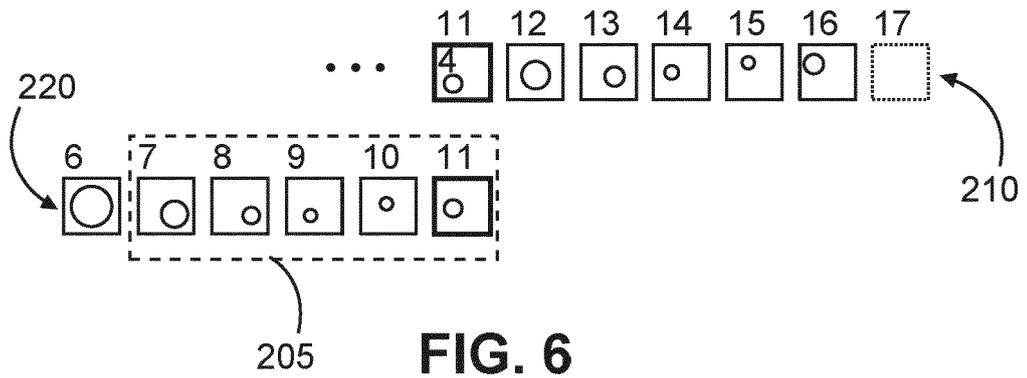


FIG. 6

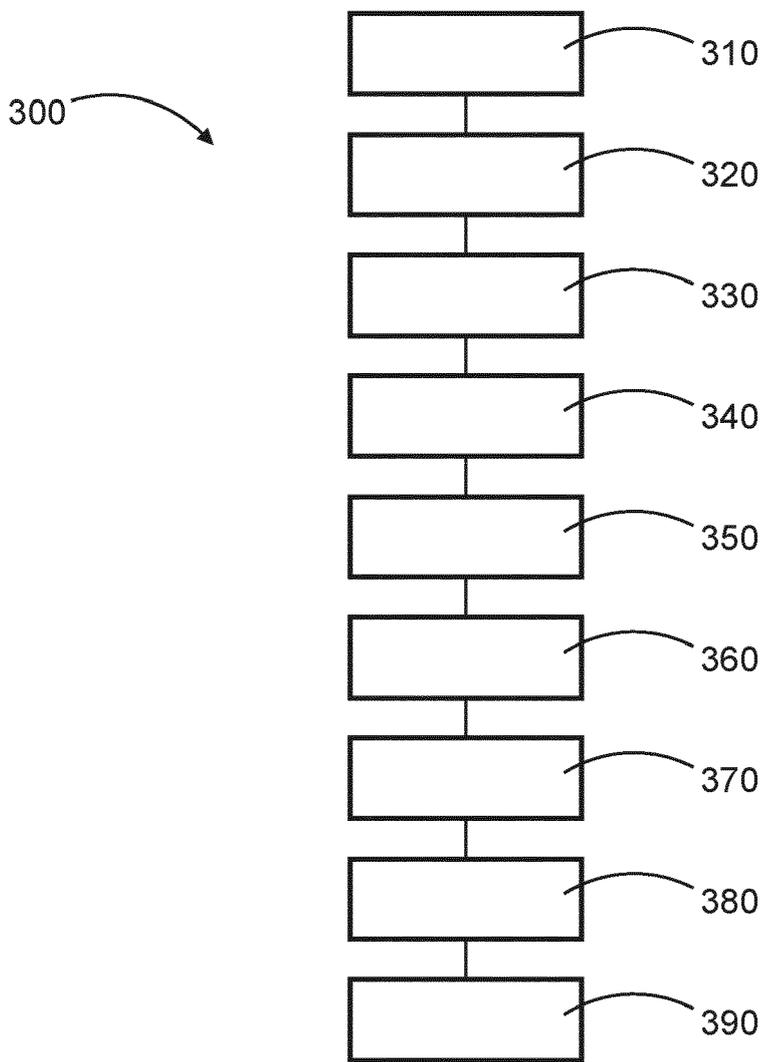


FIG. 7



EUROPEAN SEARCH REPORT

Application Number
EP 20 15 7687

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2016/354155 A1 (HODGES WESLEY BRYAN [CA] ET AL) 8 December 2016 (2016-12-08) * abstract * * figures 2,3,5A,12 * * paragraphs [0052] - [0056], [0078], [0125] - [0129] * -----	1,4-8, 10-12, 14,15	INV. G06T7/254 G06T11/60 G06T19/00
X	US 2019/122330 A1 (SAGET EDOUARD [US] ET AL) 25 April 2019 (2019-04-25) * abstract * * figures 1A,1B,5B,5C,31 * * paragraphs [0078] - [0088], [0092], [0095], [0096], [0101] - [0103], [0158] - [0160] * -----	1,11,14, 15	
X	JANNICK P. ROLLAND ET AL: "Optical Versus Video See-Through Head-Mounted Displays in Medical Visualization", PRESENCE: TELEOPERATORS AND VIRTUAL ENVIRONMENTS, vol. 66, no. 4, 1 June 2000 (2000-06-01), pages 167-309, XP055133524, ISSN: 1054-7460, DOI: 10.1162/105474600566808 * abstract * * figures 1-4,9,10 * * sections 1-3 * -----	1-3,9, 11,13-15	TECHNICAL FIELDS SEARCHED (IPC) G06T
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 18 June 2020	Examiner Scholz, Volker
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.

EP 20 15 7687

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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18-06-2020

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2016354155 A1	08-12-2016	AU 2014231343 A1	05-11-2015
		AU 2014386694 A1	13-10-2016
		CA 2903088 A1	18-09-2014
		CA 2942417 A1	17-09-2015
		CN 105163684 A	16-12-2015
		CN 106232047 A	14-12-2016
		EP 2967347 A1	20-01-2016
		HK 1216707 A1	02-12-2016
		JP 6611612 B2	27-11-2019
		JP 2016518148 A	23-06-2016
		JP 2017514637 A	08-06-2017
		JP 2019213904 A	19-12-2019
		SG 10201707562P A	29-11-2017
		SG 11201507611U A	29-10-2015
		US 2016067007 A1	10-03-2016
		US 2016354155 A1	08-12-2016
		US 2017245940 A1	31-08-2017
WO 2014139021 A1	18-09-2014		
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US 2019122330 A1	25-04-2019	NONE	
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